

DAG- TM



Key Elements:

- Free Maneuvering for user-preferred separation assurance and local traffic flow management (TFM) conformance
- Trajectory Negotiation for user-preferred separation assurance and local TFM conformance
- Collaboration for mitigating local TFM constraints
- Self-spacing for merging and in-trail separation

Benefits:

- Increased airspace system throughput through increased productivity enabled by:
 - Distribution of separation responsibility to equipped aircraft
 - ATM automation enhanced by CNS technologies
- Increased user efficiency and flexibility, resulting in reduced user direct operating costs
- Increased system safety

R&D Activities:

- Validation, assessment, and refinement of concept elements through simulation and flight trials
- Development of research prototype for air and ground systems
- Assessment of cost/benefit and safety cases

More Information:

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Distributed Air/Ground Traffic Management



Vision

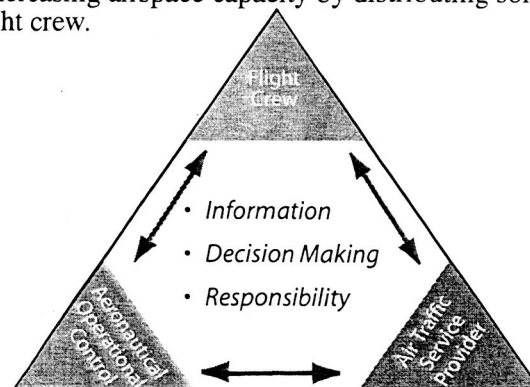
Distributed Air/Ground (DAG) Traffic Management (TM) is an integrated operational concept in which flight deck crews, air traffic service providers and aeronautical operational control personnel use distributed decision-making to enable user preferences and increase system capacity, while meeting air traffic management (ATM) requirements. It is a possible operational mode under the Free Flight concept outlined by the RTCA Task Force 3.

The goal of DAG-TM is to enhance user flexibility/efficiency and increase system capacity, without adversely affecting system safety or restricting user accessibility to the National Airspace System (NAS). DAG-TM will be accomplished with a human-centered operational paradigm enabled by procedural and technological innovations. These innovations include automation aids, information sharing and Communication, Navigation, and Surveillance (CNS) / ATM technologies. The DAG-TM concept is intended to eliminate static restrictions to the maximum extent possible. In this paradigm, users may plan and operate according to their preferences – as the rule rather than the exception – with deviations occurring only as necessary. DAG-TM is a proposed concept for gate-to-gate NAS operations beyond the year 2015. Out of a total of 15 concept elements, 4 have been selected for initial studies (see Key Elements in sidebar). DAG-TM research is being performed at Ames, Glenn, and Langley Research Centers.

High-fidelity Air-Ground Simulation (June-July 2004)

Real-life pilots and air traffic controllers put key components of the DAG-TM concept to the test in a joint simulation at the NASA-Langley Air Traffic Operations Laboratory in Virginia and the NASA-Ames Airspace Operations and Flight Deck Display Research Laboratories in California. NASA researchers integrated sophisticated computer software for "autonomous flight management" with modern cockpit systems to give flight crews the ability to plot their best flight paths. The on-board system allows aircraft to maneuver safely around traffic and airspace hazards, such as weather, while still meeting traffic flow constraints issued by ground-based controllers. During the simulation, advanced ground-based systems for air traffic control were also tested.

NASA researchers have developed computer software that assists air traffic controllers in planning the traffic flow and managing aircraft not equipped with the autonomous flight management system. Preliminary results indicate the possibility of increasing airspace capacity by distributing some air traffic control tasks to the flight crew.



McTMA



Purpose:

Assist traffic management coordinators (TMCs) anticipate future demand across multiple ARTCCs and regulate traffic flow into the TRACON.

Users:

- En route TMCs
- En route radar controllers
- Terminal area TMCs

Field Sites:

New York, Cleveland, Boston, and Washington ARTCCs, Philadelphia TRACON and the ATCSCC

Operational Results:

- TMA-SC is operational at 8 ARTCCs as part of the FAA's Free Flight program.
- Several TMA-SC sites have shown a 3-5% increase in throughput as well as reduced internal departure delays.
- Phase I of McTMA field activities (completed in May 2003) successfully demonstrated the sharing of ETA information between facilities.

Future:

- Additional McTMA field trials testing a new scheduler will take place January - June 2004.
- McTMA is an integral component of the FAA's Free Flight Phase 2 Program.

Multi-Center Traffic Management Advisor



Overview

Traffic management coordinators (TMCs) and en route (Center) air traffic controllers manage and control arrival traffic into busy terminal areas (Terminal Radar Approach Controls, or TRACONs). The Single-Center Traffic Management Advisor (TMA-SC), a decision-support tool (DST) developed at NASA Ames Research Center and deployed as part of the FAA's Free Flight Phase 1 program, assists Center TMCs and air traffic controllers in flow management planning where a single Center is responsible for managing traffic to a terminal area.

Multi-Center TMA (McTMA) is a DST that will expand the TMA-SC planning horizon and facilitate traffic flow management and coordination between multiple ATC facilities. McTMA will help to address congestion issues where more than one Center affects traffic to a terminal area, common in the Northeast Corridor of the United States. Sectors in the Northeast are often narrow and congested, with complex, interacting traffic flows. Current flow restrictions that are implemented to manage this multi-Center traffic environment can be inefficient, resulting in no-notice holding and overly conservative miles-in-trail operations.

McTMA provides an effective communications infrastructure between facilities to share predictions of aircraft arrivals, provide improved flow visualization capabilities, and generate schedules for traffic through multiple Centers. With this set of shared information, TMCs will be able to better address congestion issues before they become no-notice holding situations. McTMA will also enable time-based metering to allocate delays to the most appropriate sectors, whether in a first- or second-tier Center.

The McTMA Schedule

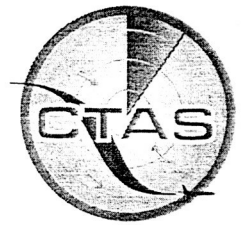
For each arrival aircraft in the system, McTMA computes the undelayed estimated time of arrival (ETA) to sector and Center boundaries, meter fixes, the final approach fix, and the runway threshold. The aircraft are then sequenced to these points on a first-come, first-served basis according to their ETAs and user-entered sequence constraints. Scheduled times of arrival (STAs) at each of these points are then computed to meet local constraints, user-defined scheduling constraints, and constraints automatically generated to ensure successive controllers will be able to meet their respective schedules.

McTMA creates a schedule well in advance of when traffic flow management decisions need to be implemented, and conveys this information to TMCs through graphical displays. In doing so, McTMA helps TMCs to devise a traffic plan and translate the traffic plan into sequences and STAs at the metering locations, maximizing airport and TRACON capacity while maintaining established separation standards. McTMA-generated schedules are displayed on the Center controllers' radar displays, where controllers determine the best strategies for meeting the schedule. McTMA continually updates its schedule at a rate comparable to the radar update rate in response to changing events (such as amount of traffic or changes in the winds) and controller and/or TMC inputs.

Initial Research Efforts

Current McTMA research, which is supported by NASA's Airspace Systems Program, focuses on arrivals into Philadelphia TRACON (PHL) that traverse New York, Washington, Cleveland, and Boston Centers. McTMA displays are installed at the five facilities, enabling them to visualize the traffic demand and shared scheduling information.

Terminal Area Automation



Purpose

Assist terminal area controllers in efficiently directing airborne arrival and departure traffic by providing scheduling, heading, speed, and altitude advisories.

Users

Terminal area and en route radar controllers
Terminal area traffic management coordinators (TMCs)
Tower controllers
Airline operations centers
Surface departure planning tools

Benefits

The FAA estimated that FAST saved airlines \$10M a year at DFW. Recent benefits studies of a national deployment of EDP estimated an annual savings of almost \$40M. Together with a surface planning tool, benefits of \$115M could be achieved.

Status

EDP simulations will be conducted to gain insight into functional and interface design requirements.

Future

FAST and EDP will be fully integrated, allowing for increased efficiency and efficiency in the TRACON.

Overview

Air traffic control specialists at Terminal Radar Approach Control (TRACON) facilities are required to manage increasingly complex traffic flows arriving and departing busy airports. NASA has developed decision support tools (DSTs) to assist terminal arrival and departure controllers and traffic management coordinators (TMCs) with managing traffic in the terminal area. These DSTs include the Final Approach Spacing Tool (FAST) and the Expedite Departure Path (EDP). These DSTs assist controllers by creating sequences and schedules for aircraft to maximize capacity and minimize delay without compromising safety. Advisories are then generated to help controllers meet these schedules. FAST and EDP can be easily integrated with one another; both tools share a common software architecture which allows communication between the tools about arrival/departure flow interdependencies. This information sharing can result in a more flexible and efficient use of the constrained terminal airspace.

The Final Approach Spacing Tool

FAST is a DST for TRACON arrival controllers. The first phase of research, Passive FAST (pFAST), provides strategic runway and sequence advisories to improve runway utilization. Continuing studies provide more tactical heading, speed, and altitude advisories to help achieve the spacing and sequencing efficiencies generated by the FAST scheduler.

Passive FAST was operationally tested at Dallas/Ft. Worth TRACON and demonstrated a 9-13% increase in landing rates. Ongoing FAST research has led to advanced terminal area research tools to enable highly accurate, fast-time simulations of DST performance. Ultimately, FAST will be used to evaluate the feasibility and potential benefits of more fully automated terminal operations.

The Expedite Departure Path

EDP is a DST which provides TRACON departure controllers with advisories to assist in managing airborne departure operations. EDP is an extension of the same scheduling algorithms developed for FAST. EDP will provide controllers with timely climb, speed and heading advisories via the controller's radar display, which can be used to merge aircraft efficiently into the en-route stream, and when possible, allow expedited climb trajectories. Using the accurate trajectory prediction capabilities within CTAS, EDP calculates efficient departure trajectories that meet flow restrictions imposed by TMCs. The high-fidelity trajectory modeling can further assist surface departure planning tools by providing accurate time-to-fly predictions for pending departures.

Environmental and Other Benefits

Terminal area arrival and departure research enables the development of capabilities that aid in achieving environmental benefits. Though improvements in terminal area efficiency alone can result in environmental benefits, the precision of terminal automation trajectories can be used to assist controllers in directing low-noise approaches, more fuel-efficient climbs and more effective noise-abatement routes.

The research has also led to the creation of a closed-loop simulation capability for CTAS to enable verification of decision algorithms and benefits estimates. With this capability, researchers are able to examine the feasibility, as well as the potential benefits, of new airspace designs and procedures.

Terminal area automation research is being supported by NASA's Airspace Systems Program.



Direct - To

Purpose:

- Improve airspace efficiency and facilitate flying time savings for airspace users.
- Provide advisories for traffic conflicts and wind-favorable direct routes.
- Provide a rapid-feedback user interface, fully integrated with R-Side display.
- Analyze conflicts, flying time, special use airspace, and preferential routes.

Users:

En route radar controllers

Field Sites:

Fort Worth ARTCC (ZFW)

Operational Results:

- Operational evaluation at ZFW with auxiliary displays in May/June 2001 demonstrated positive controller feedback and validated reduction in flying time.
- National controller team evaluations of R-Side prototypes in April and September 2002

Future:

Follow-on R-Side evaluations planned for January 2003.

Overview

Direct-To (D2) is a decision-support tool for en route radar controllers which helps improve airspace efficiency, simplifies the analysis and input of route and altitude changes, and facilitates flying-time savings for airspace users. D2 continuously analyzes all aircraft for potential traffic conflicts and for wind-favorable direct routing ("direct-to") opportunities. Conflict advisories and direct-to route advisories are provided with minimal additional impact to the controller's display; information is added to the full data block and can be accessed through optional lists. A highly-automated trial planning function allows controllers to quickly visualize, evaluate, and input route and altitude amendments. D2 research is supported by NASA's Airspace Systems Program.

System Description

D2 is based on the Center-TRACON Automation System (CTAS) trajectory analysis methodology and software. CTAS computes 4-dimensional trajectory predictions for all aircraft based on radar track and flight plan data from the ARTCC (Center) Host, atmospheric data from the National Weather Service and aircraft performance models. All trajectory predictions are recomputed with every 12-sec. radar track update, periodic flight plan updates, and hourly atmospheric data updates. Traffic conflict and direct route advisories are recomputed every 6 seconds. Trial plan status information (conflict, flying time, special use airspace, preferential routing) is updated every second.

Direct route advisories are based on a wind-route algorithm that continuously analyzes all aircraft in the system and identifies those that can save at least one minute in flying time by flying direct to a downstream fix on their route of flight. Route advisories are constrained to prevent significant deviation from the planned route of flight. The wind-route algorithm is also activated whenever the trial planner is utilized for any aircraft, which allows the controller and pilot to consider the effect on flying time when evaluating a route change.

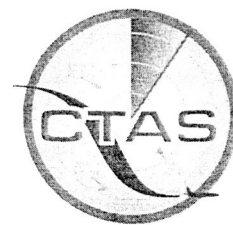
User Interface

D2's functionality is fully integrated with the R-Side traffic situation display. Track-ball clicks are used to: display a graphical depiction of potential conflict geometry, activate a trial-planning function, or activate an altitude probe. The trial-planning function graphically displays the route with an analysis of potential traffic conflicts, special use airspace, preferential routes, and flying time. The controller can then use the trial planner to modify the route easily by a point-and-click action and either select a different fix or add an auxiliary waypoint, and then input the flight plan amendment to the Host computer. The altitude probe computes and displays the conflict status for all relevant climb- (or descend-) and-maintain trajectories.

Operational Evaluations

Over 50 controllers from 9 Centers have participated in the development of D2, which was first operationally tested using auxiliary displays at Denver Center in 1997 as the Conflict Probe/Trial Planner. More recent evaluations at ZFW were conducted in November 1998 and May/June 2001. Efforts are currently underway to implement the D2 functionality on the DSR R-Side traffic display; this implementation is being evaluated by a national controller team including representatives from Air Traffic's Conflict Probe Team and DSR Evolution Team. R-Side simulations were conducted at the FAA's William J. Hughes Technical Center in April and September 2002 and additional simulations are scheduled for January 2003. Operational results show a potential for saving 900 minutes per day in flying time if D2 were operational throughout Fort Worth ARTCC (ZFW). Simulation data show similar potential savings nationwide.

Surface Management System



Overview

The Surface Management System (SMS) is a decision support tool that will help controllers, traffic managers, and NAS users manage the movements of aircraft on the surface of busy airports, improving capacity, efficiency, and flexibility. The Advanced Air Transportation Technologies (AATT) Project at NASA is developing SMS in cooperation with the FAA's Free Flight Phase 2 (FFP2) program. SMS consists of three parts: a traffic management tool, a controller tool, and a National Airspace System (NAS) information tool.

Traffic Management Tool

SMS supports traffic management functions in the ATC tower, Terminal Radar Approach Control (TRACON) and Center. Accurate information about future departure demand and the resulting impact on surface operations is not currently available. SMS uses surface and airborne surveillance, along with updated air carrier pushback schedules, to predict the future demand and how that demand will affect the airport surface (e.g., what delays and queues will result and when). Shared awareness of these predictions support various traffic management decisions. For example, at airports where arrival and departure capacities are interdependent and must be coordinated, SMS predictions can be used to compare various possible traffic management actions. Interoperability between SMS and the CTAS Traffic Management Advisor (TMA) was studied during a January 2002 simulation, demonstrating the ability of TMCs to reduce arrival and departure delays when provided with better information.

Controller Tool

SMS helps Local and Ground controllers in the ATC tower construct efficient departure queues by providing runway departure advisories. SMS likewise helps ramp tower controllers in improving the efficiency with which runways are utilized by aiding in the creation of improved departure sequences and schedules. SMS also enables coordination between the ATC tower and ramp towers, for example, when a departure needs to exit an alley on the ramp before an arrival enters the ramp.

NAS Information Tool

SMS will provide surface predictions to the Enhanced Traffic Management System (ETMS) for use in traffic flow management (TFM) applications and further dissemination to NAS users. These highly accurate predictions of when aircraft will take off will result in more accurate demand predictions and will improve NAS-wide predictability. SMS landing and gate arrival time predictions support NAS user decision making.

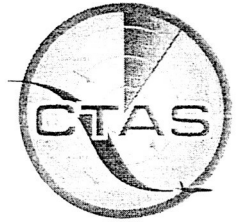
Accomplishments

Two SMS simulations were conducted in NASA's Future Flight Central ATC tower simulator in September 2001 and January 2002. FAA controllers and air carrier representatives provided feedback to SMS researchers on the SMS concept, user interfaces, and algorithm performance, all of which was used to refine SMS.

Operational demonstrations were conducted at the FedEx ramp tower at Memphis International Airport in August and October 2002. An operational trial was conducted at Memphis Air Traffic Control Facilities (Tower, TRACON, and Center) and at the FedEx ramp tower in September 2003. During these events, the FAA's SafeFlight 21 surface surveillance prototype was used for real-time aircraft location and identification.

EDA

En Route Descent Advisor

**Purpose:**

Provide controllers with advisories for precision arrival metering

Capabilities:

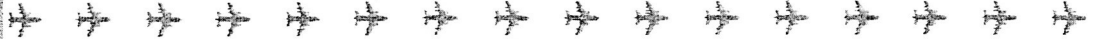
- Displays "meet-time" advisories involving speed, altitude, and heading maneuvers
- Integrates with TMA arrival schedule for precise arrival performance and uses TMA timeline display for metering conformance feedback
- Displays advised routing along with top-of-descent location
- Incorporates strategic conflict avoidance into advisories for metering, at controller's discretion

Users:

En route sector controllers

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**Overview**

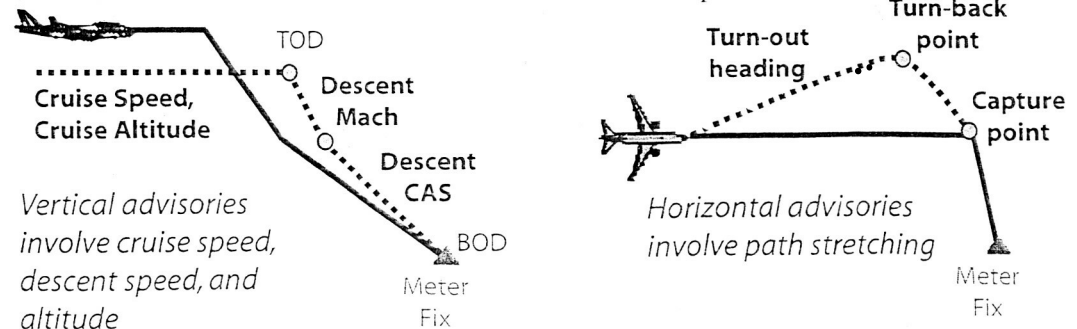
The En Route Descent Advisor (EDA) is a CTAS tool that assists controllers with metering arrival aircraft in transition from Center to TRACON airspace. Specifically, EDA generates maneuver advisories to deliver aircraft very accurately to an arrival-metering fix located at the TRACON boundary. EDA works in conjunction with the CTAS Traffic Management Advisor (TMA), which generates the precise schedules and sequences that EDA targets for optimal throughput into the TRACON. EDA is capable of generating explicit "meet-time" maneuver advisories based on combinations of speed, altitude, and heading degrees of freedom. EDA constructs advisories that satisfy ATC constraints while remaining as fuel-efficient as possible for airspace users. In addition to its meet-time capabilities, EDA provides automated conflict resolution by presenting advisories that are predicted to put aircraft on conflict-free trajectories to the metering fix. By making use of accurate CTAS trajectory predictions involving aircraft type, atmosphere, and procedures, EDA supports both strategic and tactical decision-making with time horizons up to 25 minutes.

Benefits

Studies suggest that EDA can lead to substantial benefits in capacity, fuel-efficiency, and controller productivity. Capacity benefits are achieved through accurate TRACON delivery in accordance with a TMA plan that is optimized for maximum throughput to the runway. Fuel efficiency is achieved through EDA's minimum-fuel trajectory planning algorithms, similar to those found in aircraft Flight Management Systems (FMS). Controller and airspace-user benefits are derived from the predictive capabilities of EDA, which allow for metering problems to be resolved upstream in a more strategic manner than is possible today without automation. Early detection and resolution of metering-related problems can help achieve a more equitable distribution of controller workload between upstream and downstream sectors. With assistance from EDA under high-workload metering conditions, controllers will be able to focus additional attention on non-metering tasks, such as responding to changing weather and airspace conditions, and accommodating user route preferences.

Research & Development

EDA research is supported by NASA's Airspace Systems Program. EDA is being implemented within CTAS through a series of prototype builds. An initial prototype has been implemented within the CTAS research baseline. Through 2005, the EDA prototype will be refined through a series of controller-in-the-loop simulations at NASA Ames. Beyond 2005, a pre-production prototype will be completed through ARTCC field-test evaluation and integration with the FAA Display System Replacement (DSR). Following initial deployment, EDA will be augmented with air/ground data-link capabilities in order to achieve additional benefits for controllers and airspace users.



FACET



Purpose:

Provide a flexible simulation environment with rapid prototyping capability for exploring new Air Traffic Management (ATM) concepts.

Users:

- NASA & FAA
- CSC
- M.I.T.
- Northwest Airlines
- Raytheon
- Volpe
- Small Businesses

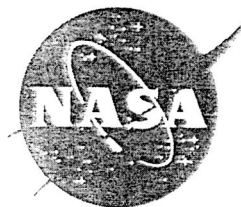
Capabilities:

- Airspace modeling over the entire U.S.
- ETMS/ASDI data interface
- Weather (RUC-2, CCFP, CIWS, NOWRAD and NCWF) data interfaces and processing
- Trajectory synthesis using round-earth equations
- Navigation using flight-plan or direct or wind-optimal routing
- Performance modeling for 500+ aircraft types
- Airspace complexity prediction using dynamic density
- Aircraft self-separation using airborne conflict detection and resolution (CD&R) methods
- System wide impact assessment of traffic flow management constraints
- 3D traffic flow visualization capabilities
- Runs on a desktop computer

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Future ATM Concepts Evaluation Tool



Description

FACET is an Air Traffic Management (ATM) modeling and simulation capability being developed at NASA Ames Research Center. The purpose of FACET is to provide an environment for the development and evaluation of advanced ATM concepts. FACET research is supported by NASA's Airspace Systems Program.

FACET is capable of modeling system-wide airspace operations over the United States. Airspace models (e.g., Center/sector boundaries, airways, SUAs, navigation aids /fixes and airports) are available from databases. Weather models (winds, temperature, severe weather cells, etc.) are also available. A core capability of FACET is the modeling of aircraft trajectories. Using round-earth kinematic equations, aircraft can be flown along either flight plan routes, direct routes or wind-optimal routes as they climb, cruise and descend according to their individual aircraft-type performance models. Performance parameters (e.g., climb/descent rates and speeds, cruise speeds) are obtained from data table lookups. Heading and airspeed dynamics are also modeled.

The design of FACET strikes an appropriate balance between flexibility and fidelity. FACET is hierarchically compatible with the Center-TRACON Automation System (CTAS) and the Airspace Concepts Evaluation System (ACES) in terms of scope and fidelity. The national-level flexible modeling capabilities of FACET complement both the mixed-fidelity gate-to-gate modeling capabilities of ACES and the Center-level high-fidelity modeling capabilities of CTAS.

FACET has been designed with a modular software architecture to facilitate rapid integration of new ATM concepts. The software is written in "Java" and "C" programming languages. It is platform independent, and can be run on a variety of computers.

Applications

Several advanced ATM concepts are implemented in FACET: aircraft self-separation; prediction of aircraft demand and sector congestion; system-wide impact assessment of traffic flow management constraints and wind-optimal routing.

